Edge Detection Algorithm of Daliushu River Based on Adaptive Weighted Morphology

Lingxiao Huang [1,2,a], Chunguang Li [3,b], Lanxiang Zheng [4,c], Hefang Jing [3,d], Xuande Zhang [5,e], Hailong Ma [6,f]

[1]School of Civil and Hydraulic Engineering, Ningxia University, Yinchuan 750021, China;
[2]School of Information Engineering, Ningxia University, Yinchuan 750021, China;
[3]School of Civil Engineering, Beifang University of Nationalities, Yinchuan 750021, China;
[4]School of Resources and Environment, Ningxia University, Yinchuan 750021, China
[5]College of Electrical and Information Engineering, Shaanxi University of Science & Technology, Xi'an 710021, China
[6]Institute of Ethnic Preparatory Education, Ningxia University, Yinchuan 750021, China
[a]hlingxiao@126.com, [b]cglizd@hot.mail.com, [c]lanxiangzheng@yahoo.com.cn, [d]jinghef@163.com, [e]love_truth@126.com, [f]mhl@nxu.edu.cn

Abstract: This paper proposes a method of river edge detection based on adaptive weighted mathematical morphology. Firstly, a multi-shape and multi-scale structural element is constructed, and the edge of Daliushu river is detected by structural elements of five shapes and four scales. Secondly, the information entropy of the river edge in each image is calculated, and the weight coefficient is determined adaptively according to the information entropy. Finally, the final resultant image is weighted by weighting coefficients. Experimental results show that the algorithm proposed in this paper can effectively extract the edge of Daliushu river compared with some classical edge detection algorithms.

Keywords: mathematical morphology, structural element, edge detection, information entropy, adaptive weighting

1. Introduction

It is very important to detect the precise waterfront boundary information of the Daliushu river by the edge detection algorithm, which is the base of our study on the numerical simulation of the flow and sediment in the Daliushu river. In the study of the existing waterfront edge information extraction(e.g.[1,2,3,4,5,6,7,8,9]), the edge detection and the edge connection of the riverbank have been carried out by the wavelet transform method combined with the ridge tracing technique [1]. In [2], the morphology and Hough transform was applied to the lock monitoring system, and the detection and location of the river edge was carried out. [3] proposed an self-adaptive thresholding Canny edge detection method to automatically extract the edge of the river area. In [4], a method of river extraction based on the graph model and river prior model is proposed. In [5], a method of river information detection based on sub-block histogram and regional characteristics is proposed. [6] designed a filter based on the frequency domain filter to achieve the high-resolution remotely sensed imagery of urban river channel information extraction. In [7], a multi-feature fusion method based on local entropy, texture and corner information features of remote sensing image is proposed.

The support vector machine method combined with geodesic active contour model is used to extract the river area. In [8], the active contour extraction algorithm is used to extract the irregular boundary of the waters on the remote sensing image. In [9], the method of cross-entropy threshold segmentation and improved image segmentation is used to realize the automatic extraction of river targets. These methods have their own specificity and characteristics, but can not achieve effective denoising while extracting complex edges. Mathematical morphology [10,11] is a non-linear filtering method. It uses different structural elements to extract different image edge features. Large-scale structural elements have strong denoising effect, but the detected edge is coarse. Small-scale structural elements have weak denoising effect, but can detect thin edge information. In this paper, an adaptive edge detection algorithm based on weighted morphological algorithm [12,13,14] is proposed to solve the noise problem and edge complexity problem of the Daliushu river image, and the edge information of complex waterfront is extracted at the same time.

2. Basic Mathematical Morphology

Mathematical morphology includes four basic operations: expansion, corrosion, open, closed.

Let the original image F and the structural element b be a set in the integer space Z. The expansion of b to F is denoted as $F \oplus b$, defined as:

$$F \oplus b = \left\{ z \middle| \left(\hat{b}\right)_z \cap F \neq \varnothing \right\} \tag{1}$$

Where $\varnothing$ is the empty set, $\hat{b}$ is the mapping of b, and $\left(\hat{b}\right)_z$ is the translation of $\hat{b}$. The expansion operation has a dilation effect, it can fill in the image of small gaps, so that the two objects occur close adhesion.

The corrosion of b to F is denoted as $F \Theta b$, defined as:

$$F \Theta b = \left\{ z \middle| \left(b\right)_z \subseteq F \right\} \tag{2}$$

Where $\left(b\right)_z$ is the translation of b. The corrosion operation has a contraction effect, it can eliminate the useless dots in the image, separating the small adhesion between two similar objects.

The opening of b to F is denoted as $F \circ b$, defined as:

$$F \circ b = (F \Theta b) \oplus b \tag{3}$$

The opening operation can smooth the image, cut off the slender lap and remove the small spikes on the object.

The closing of b to F is denoted as $F \bullet b$, defined as:

$$F \bullet b = (F \oplus b) \Theta b \tag{4}$$

The closing operation can smooth the image, overlay short breaks and fill small gaps or holes in the object.

3. Edge Detection Based on Adaptive Weighted Mathematical Morphology

3.1 Edge Detection of Mathematical Morphology

Commonly mathematical morphology edge detection algorithm has three kinds: corrosive edge detection algorithm, expansive edge detection algorithm and expansive and corrosive edge detection algorithm, defined as:

$$R_O = F - (F \Theta b) \tag{5}$$

$$R_T = (F \oplus b) - F \tag{6}$$

$$R_S = (F \oplus b) - (F \Theta b) \tag{7}$$

Corrosive edge detection result image R_O will lose some edge detail information in the image, expansive edge detection result image R_T will blur the edge of the image, and expansive and corrosive edge detection result image R_S will preserve the edge detail of the image and small the edge of the image blur.

In this paper, we improve (7) to construct a new edge detection algorithm:

$$R_F = (F \circ b) \oplus b - (F \bullet b) \Theta b \tag{8}$$

The improved edge detection result image can detect more detailed waterfront edge information of the Daliushu river image.

3.2 Improved Mathematical Morphological Edge Detection

The above algorithms only consider one shape and one scale structure element, but the choice of structure element plays an important role in the edge detection of mathematical morphology. The shape and scale of structure element will influence the accuracy and efficiency of edge detection.

Different shapes of structural elements can affect the accuracy of waterfront edge detection. The waterfront edge information of the Daliushu river image is complex, with different directions of edge information, need to use different shapes of structural elements to detect. In this paper, five kinds of structural elements are used, taking the 3 × 3 scale as an example：

$$\begin{bmatrix} 0 & 0 & 0 \\ 1 & 1 & 1 \\ 0 & 0 & 0 \end{bmatrix}, \begin{bmatrix} 0 & 1 & 0 \\ 0 & 1 & 0 \\ 0 & 1 & 0 \end{bmatrix}, \begin{bmatrix} 0 & 1 & 0 \\ 1 & 1 & 1 \\ 0 & 1 & 0 \end{bmatrix}, \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}, \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \end{bmatrix} \tag{9}$$

5 different shapes of structural elements match different directions of the waterfront edge. It can improve the accuracy of waterfront edge matching.

Different scales of structural elements affect the efficiency and accuracy of waterfront edge detection. Small-scale structural elements lead to fast computing speed and weak anti-noise ability, but the details of waterfront edge detection are better. Large-scale structural elements lead to slow computing speed and strong anti-noise ability, but the details of waterfront edge detection are fuzzy. Therefore, this paper uses 3 × 3 × 4 × 4, 5 × 5, 6 × 6 four different scales of structural elements to reduce the impact of image and improve the edge detection efficiency and accuracy.

In this paper, we construct the multi-shape and multi-scale structure element b_{ni}, where i is the shape of the structure element, and the range of i is $i = 1, 2, 3, 4, 5$, where n is the scale of the structure element and the range of n is $n = 3, 4, 5, 6$. In this paper, 20 edge detection images can be obtained by using five kinds of structures and four kinds of structural elements.

On the basis of Eq. (8), an edge detection algorithm of multi-shape multi-scale structure element is constructed:

$$R_{ni} = (F \circ b_{ni}) \oplus b_{ni} - (F \bullet b_{ni}) \Theta b_{ni} \tag{10}$$

According to Eq. (10) to calculate the edge detection results of the each shape and each scale structural elements. The results of the edge detection R_{ni} need to be weighted synthesis operations, defined as:

$$R_n = \sum_{i=1}^{5} p_i R_{ni} \tag{11}$$

$$R = \sum_{n=3}^{6} p_n R_n \tag{12}$$

Among them, p_i is the weight of the edge detection image of a scale and five shapes of structure elements, R_n is the edge detection result of a scale and five shapes of structure elements, p_n is the weight of the edge detection image of four scale structure elements, and R is a composite new edge detection image.

Weights p_i and p_n can be defined as the ratio of the information entropy after the edge detection to the total information entropy:

$$p_i = H_i \Big/ \sum_{i=1}^{5} H_i \tag{13}$$

$$p_n = H_n \Big/ \sum_{n=3}^{6} H_n \tag{14}$$

Information entropy reflects the richness of image information, but also directly reflects the proportion of different edges, defined as:

$$H = -\sum_{i=1}^{256} P_i \log_2(P_i) \tag{15}$$

Where P_i is the ratio of the pixels in the image with the gray value of i to the total pixels in the image.

3.3 This Paper Describes the Algorithm

1) The edge detection of Eq. (9) is carried out by using five shapes structural elements with the scale of three, and the information entropy of Eq. (14) is calculated for the five edge detection results, and the edge detection images are synthesized by Eq. (12) and Eq. (10) to obtain the edge detection result R_3 with the scale of three.

2) The result R_4 of edge detection at scale four is obtained by using the above-mentioned operations with five shapes structural elements with the scale of four .

3) Similarly, edge detection results R_5 and R_6 are obtained at scales five and six, respectively.

The information entropies of Eq. (14) are calculated for the edge detection results at four scales, and the edge detection image is synthesized by Eq. (13) and Eq. (11) to get the final synthesis result R.

4. Experimental Results and Analysis

Under the condition of Matlab7, the edge detection of the Daliushu river image acquired by GE software is carried out. In order to detect the effectiveness of the proposed algorithm, the classical Sobel algorithm, the expansive and corrosive edge detection algorithm and the adaptive weighted mathematical morphology edge detection algorithm proposed in this paper are compared and analyzed. Fig. 1 shows the original image, Fig. 2 shows the edge detection result of the Sobel algorithm, Fig. 3 shows the edge detection result of the expansive and corrosive edge detection algorithm. Fig.4 is the result of edge detection by the adaptive weighted mathematical morphology edge detection algorithm. The results show that the Sobel edge detection is not good, and the noise suppression is not strong. The expansive and corrosive edge detection algorithm is more accurate but not continuous, and the ability of suppressing noise is improved. The adaptive weighted mathematical morphology edge detection algorithm proposed in this paper can detect the edges accurately and continuously, and the noise suppression ability is strong.

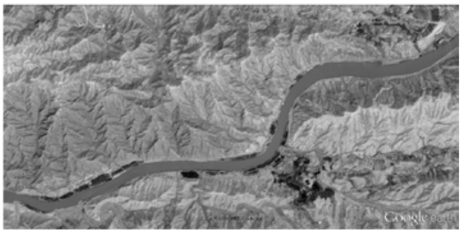

Fig.1 Original image

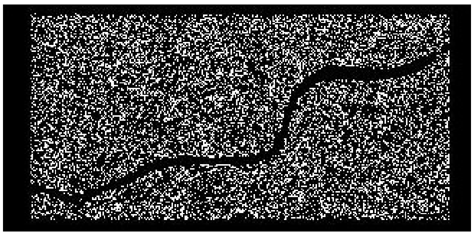

Fig.2 Sobel edge detection

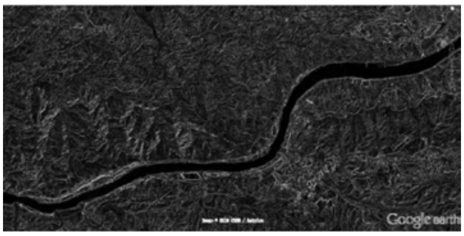

Fig.3 Expansion and corrosion type edge detection

Fig.4 The paper algorithm edge detection

5. Conclusions

In this paper, the adaptive weighted mathematical morphology edge detection algorithm is proposed, which improves the general edge detection algorithm and can keep the details of the waterfront edge of the Daliushu river. It can effectively suppress the noise in Daliushu river image, and also provides a basis for the extraction of the river edge latitude and longitude information and the pretreatment of the river terrain.

6. Acknowledgments

This work was supported by the National Natural Science Foundation of China (41301533，51468053,61362029,11361002) and Scientific Research Fund of Ningxia University (ZR16018). And Mr. Li Chunguang is the Corresponding author.

References

[1] Jinping Sun, Shiyi Mao. River Detection Algorithm in SAR Images Based on Edge Extraction and Ridge Tracing Techniques[J]. International Journal of Remote Sensing, 2011, 32(12):3485-3494.

[2] Chunjuan Li, Yong He. A Method of River Edge Detection Based on Morphology and Hough Transform[J]. Journal of Luoyang Institute of Science and Technology(Natural Science Edition), 2013,23(4):66-69.

[3] Jianjun Zhao, Heng Yu, Xiaoguang Gu, et al. The Edge Detection of River Model Based on Self-adaptive Canny Algorithm and Connected Domain Segmentation[C]// 2010 8th World Congress on Intelligent Control and Automation(WCICA 2010), School of Control Science and Engineering, Shandong University, Jinan, Chian, 7-9 July 2010, Institute of Electrical and Electronics Engineers(IEEE),2010:1333-1336.

[4] He Zhu, Chenming Li, Lili Zhang, et al. Graph Model and River Prior Model Based River Extraction in SAR Images[J]. Remote Sensing Technology and Application, 2015,30(2):337-344.

[5] Chao Wang, Fengchen Huang, Xiaobin Tang, et al. A River Extraction Algorithm for High-resolution SAR Images with Complex Backgrounds[J]. Remote Sensing Technology and Application,2012,27(4): 516-522.

[6] Ke Wang, Pengfeng Xiao, Xuezhi Feng, et al. Extraction of Urban Rivers from High Spatial Resolution Remotely Sensed Imagery Based on Filtering in the Frequency Domain[J]. Journal of Remote Sensing, 2013,17(2):269-285.

[7] Xiaosheng Yu, Chengdong Wu, Dongyue Chen, et al. River Detection in Remote Sensing Image Based on Multi-feature Fusion[J]. Journal of Northeastern University:Natural Science,2012,33(11): 1547-1550.

[8] Shulong Zhu, Weican Meng, Baoshan Zhu. Irregular Water Boundary Extraction Using GVF Snake[J]. Journal of Remote Sensing, 2013,17(4):742-758.

[9] Yiquan Wu, Yu Song. River Target Detection by Combining Reciprocal Cross Entropy Thresholding and Improved Graph Cuts[J]. Journal of Harbin Engineering University, 2015,36(6):836-840.

[10] Chen XU, Hui LIU, WenMing CAO, et al. Multispectral Image Edge Detection Via Clifford Gradient[J].Science China(Information Sciences),2012,55(2):260-269.

[11] Yiquan Wu, Li Zhu, Yabing Hao, et al. Edge Detection of River in SAR Image Based on Contourlet Modulus Maxima and Improved Mathematical Morphology[J]. Transactions of Nanjing University of Aeronautics and Astronautics, 2014,31(5):478-483.

[12] Junqing Yu, Runqiu Wang, Taoran Liu, et al. Seismic Energy Dispersion Compensation by Multi-scale Morphology[J]. Petroleum Science,2014,11(3):376-384.

[13] Jingwang Wen, Licui Ling, Yunchen Dao. Multi-scale Morphology Analysis of Acoustic Emission Signal and Quantitative Diagnosis for Bearing Fault[J]. Acta Mechanica Sinica, 2016,32(2):265-272.

[14] SA Coleman, BW Scotney, S Suganthan. Multi-scale Edge Detection on Range and Intensity Images[J]. Pattern Recognition, 2011,44(4):821-838.